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AIR MINISTRY

METEOROLOGICAL RESEARCH COMMITTEE

An electrical dewpoint hygrometer suitable for routine meteorological use

by

J. MacDowall (Meteorological Office)

Introduction

The principle of this instrument was first described by W. Findeisen (1935), and consists of the determination of the dewpoint of a surface coated with a hygroscopic substance. The advantage of this method is that the dewpoint of such a surface is usually above air temperature so refrigeration is not required. This idea has been developed by the Foxboro Instrument Company in the U.S.A. in their Dewcel and first adapted for meteorological use by John H. Conover (1950) who found it accurate to ±3°F. of the dewpoint determined with an Assmann psychrometer. This paper describes a hygrometer similar to Conover's and comparisons with an Assmann psychrometer, twice a day (at about 0930 and 1700 local time) for six months. At the same time the dewpoint was measured with wet and dry bulb thermometers inside a large type of Stevenson screen.

2. Description of the instrument

(i) The hygrometer consists of a varnished brass tube 3 in. long, ½ in. diameter covered with glass tape impregnated with lithium chloride on top of which are wound two parallel silver wires about 3/32 in. apart and insulated from each other at both ends. A supply of about 30 volts A.C. is connected to the two wires through a ballast resistance in the form of a 35v. 100w. lamp. The temperature of the hygrometer is measured with a mercury in glass thermometer with the bulb placed in the centre of the brass tube. A photograph of the element is shown in Fig.1 and the circuit in Fig.2.

(ii) The element and thermometer are mounted with the axis vertical at the centre of the double walled wind shield shown in Figs. 3 and 4. In operation the hygrometer is mainly between 30°F. and 70°F. above air temperature so an air circulation is set up inside the wind shield*.

3. Operation of the hygrometer

The temperature variation of the vapour pressure over a surface of water and a surface of a saturated lithium chloride solution is shown in Fig. 5. From this it can be seen that with the hygrometer at air temperature the lithium chloride will draw water from the atmosphere providing the R.H. is greater than about 10%. Consequently the electrical resistance between the two silver wires is very small (under 1 ohm) and a large current, limited by the ballast lamp,

/will

*Footnote. From Table 1, with an air temperature of 50°F. this corresponds to a R.H. of between 100% and 30%.

will flow between the two wires warming up the hygrometer. When the temperature of the hygrometer exceeds its equilibrium temperature (the dewpoint of lithium chloride) water will be evaporated from the glass tape, thus cutting off the current. Eventually the hygrometer will regulate itself at this equilibrium temperature. The dewpoint of the air surrounding the hygrometer is then determined from Fig.6. Clearly the instrument will not operate when the hygrometer temperature is below air temperature; the minimum measurable relative humidity is shown in Fig.7.

4. Comparison with an Assmann psychrometer

The instrument was first set up in September 1954 and has run without attention for over a year. From March to September 1955 simultaneous observations of dewpoint have been made with an Assmann psychrometer, the electrical hygrometer and the thermometers in a large Stevenson screen; wind and cloud cover were noted at the time of observation. The most notable operational features of this investigation were the great reliability of the electrical hygrometer and the simplicity of an observation below the freezing point. On these occasions it would take as much as half an hour to get a satisfactory reading of the screen ice bulb. No difficulty was experienced with the Assmann psychrometer in these conditions. During the period the screen muslin was changed weekly and the psychrometer observations were computed using a M.O. humidity slide rule. Hygrometer observations were converted to dewpoint using the curve shown in Fig.6, readings from which are tabulated in Table 1. Exposed stem corrections have been applied to all readings of the hygrometer. Fig.6 also shows the experimental result of Conover, a hygrometer calibration derived from the International Critical Tables and figures based on a determination of the vapour pressure over saturated lithium chloride by Wexler and Hasegawa (1954). The roof site at Harrow used for the experiment is shown in Fig.8.

Table 1

Hygrometer temperature °F.	52.5	66.0	79.5	92.9	106.0	119.8	133.9	148.5	163.8	179.8
Dewpoint °F.	0	10	20	30	40	50	60	70	80	90

5. Analysis and presentation of observations

The results are expressed as the difference between the hygrometer dewpoint and Assmann dewpoint, or the difference between the screen and Assmann psychrometer. The presentation used in Figs.9-14 is the integral distribution curve of the hygrometer and screen errors, the ordinate showing the percentage of observations whose error is less than or equal to the value of the abscissa. The mean of the errors considered is marked on these graphs.

In addition to the overall behaviour of the instruments shown in Fig.9 the observations are split into the groups shown in Table 2 to examine the effects of radiation, wind and relative humidity.

/Table 2

Table 2

Effect	Groups compared	No. of obs.	Fig.
(i) Radiation	Days with $\geq$ 6/8 Cloud Days with $\leq$ 2/8 Cloud	130 50	10,11
(ii) Wind	Wind $\leq$ 5 kt. 5 < Wind $\leq$ 10 kt. Wind > 10 kt.	40 50 40	12,13
(iii) Relative humidity	50° $\leq$ (Hygrometer-Air) < 60°F. 60° $\leq$ (Hygrometer-Air) < 70°F.	40 60	14

We will now consider the significance of these curves.

(i) All observations

In Fig.9, the electrical hygrometer can be seen to have an overall scatter similar to the screen, but the scatter of negative errors is greater than for the screen, which shows a fairly sharp cut off. A surprising feature of the screen observations is the mean error of + 1.0°F. which could be due to an error in the psychrometer constants used. This error has been investigated by four stations, two in the south of England and two in Scotland, and shows that the error and scatter are in some way connected with poor exposure.

(ii) Effect of radiation

This is the most serious effect on the instrument, the difference between the means of cloudy and clear days being 1.4°F. compared with 0.4°F. for the screen. As no attempt has been made to protect the wind shield from radiation it should be possible to reduce this error to about 0.5°F.

(iii) Effect of wind

The deterioration in the performance of a screen due to insufficient ventilation can be seen in Fig.13 but no systematic change in the performance of the hygrometer with wind speed, measured about 30 ft. above the screen, can be detected in Fig.12. On the other hand an unshielded instrument shows a marked variation in calibration with wind speed. This effect has been examined in a wind tunnel for transverse air flow over the hygrometer and the results are presented in Fig.15.

(iv) Variation with relative humidity

This is due to the changes in the rate of loss in heat caused by variations in the difference between the hygrometer temperature and air temperature. The magnitude of the effect is small but clearly detectable in Fig.14*.

A similar effect must exist in a screen due to the exposed stem and conduction errors but is partially compensated by the value used for the psychrometric constant.

6. Conclusions

This electrical hygrometer has been shown to be capable of a higher accuracy in the measurement of dewpoint than the ±3°F. claimed by Conover. The errors have been examined to show up the effect of radiation, relative humidity and wind. Radiation is shown to have an effect on the reading. As no attempt has been made to protect the shield against radiation a significant reduction in this error should be possible.

*An electrical hygrometer temperature - air temperature difference of 70°F. corresponds to a relative humidity of about 100%; and 50°F. to about 50% R.H., at an air temperature of about 70°F.

The electrical hygrometer is ideally suited for the continuous recording of dewpoint. Air temperature and dewpoint can be recorded on the same scale with similar thermometers, providing the hygrometer thermometer is fitted with fixed shunt and series resistors. Using a platinum resistance thermometer this device may be used over a range of dewpoints from -20°F. to +70°F. with a maximum correction of about 2°F.

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Wexler, A. and Hasegawa, S. Relative humidity temperature relationship of some saturated salt solutions. Jour. Res. N.B.S., Vol. 53, No.1, pp.19-25. (July 1954).

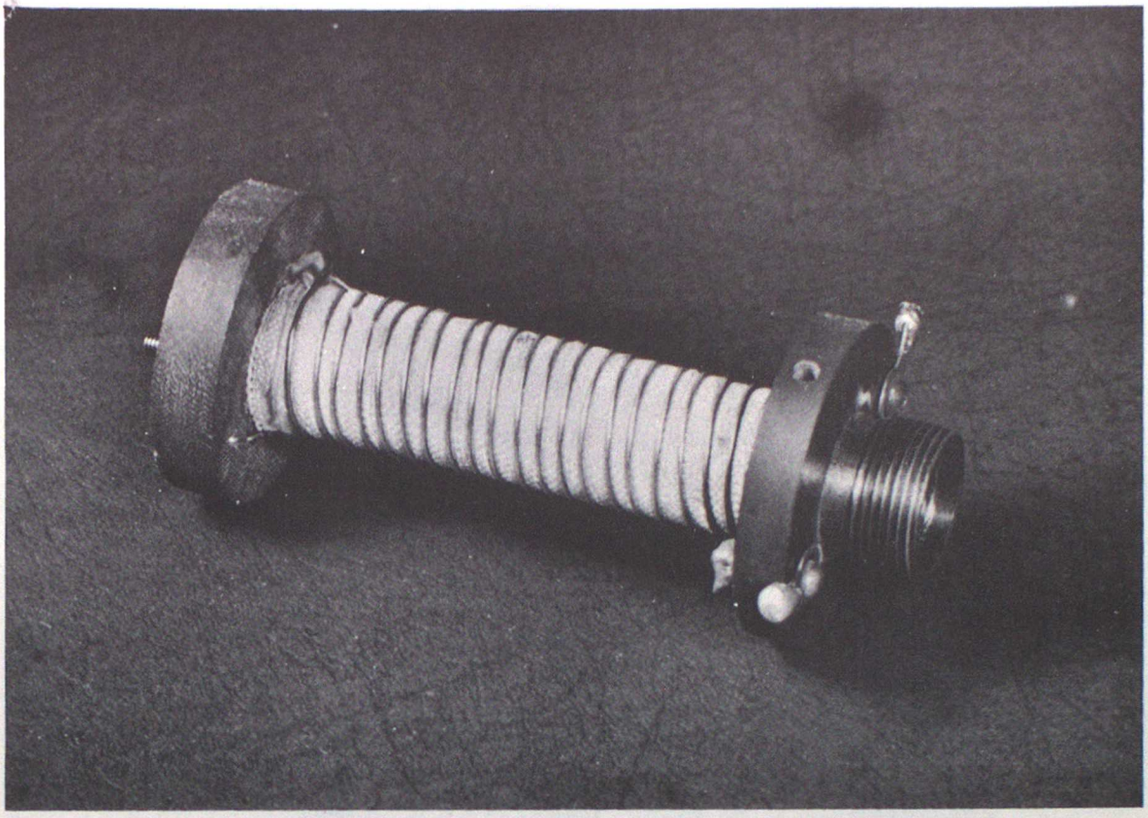

Fig. 1. THE HYGROMETER ELEMENT.

ELECTRICAL HYGROMETER CIRCUIT

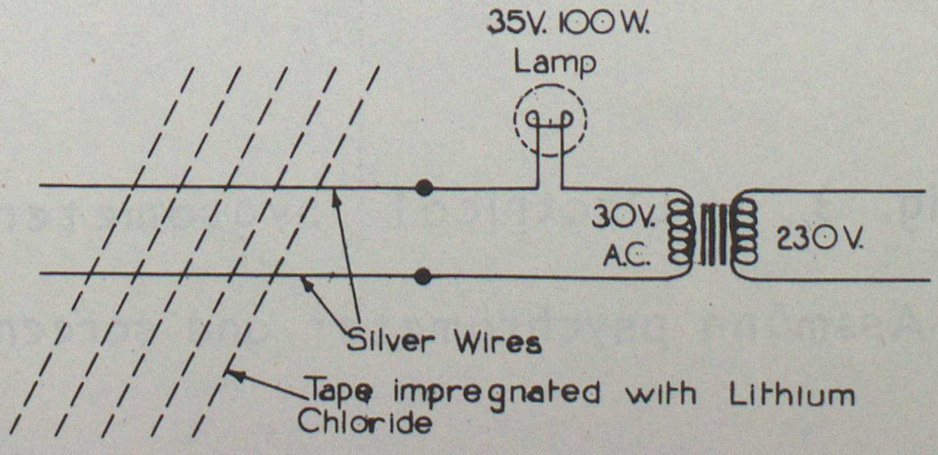

Fig. 2.

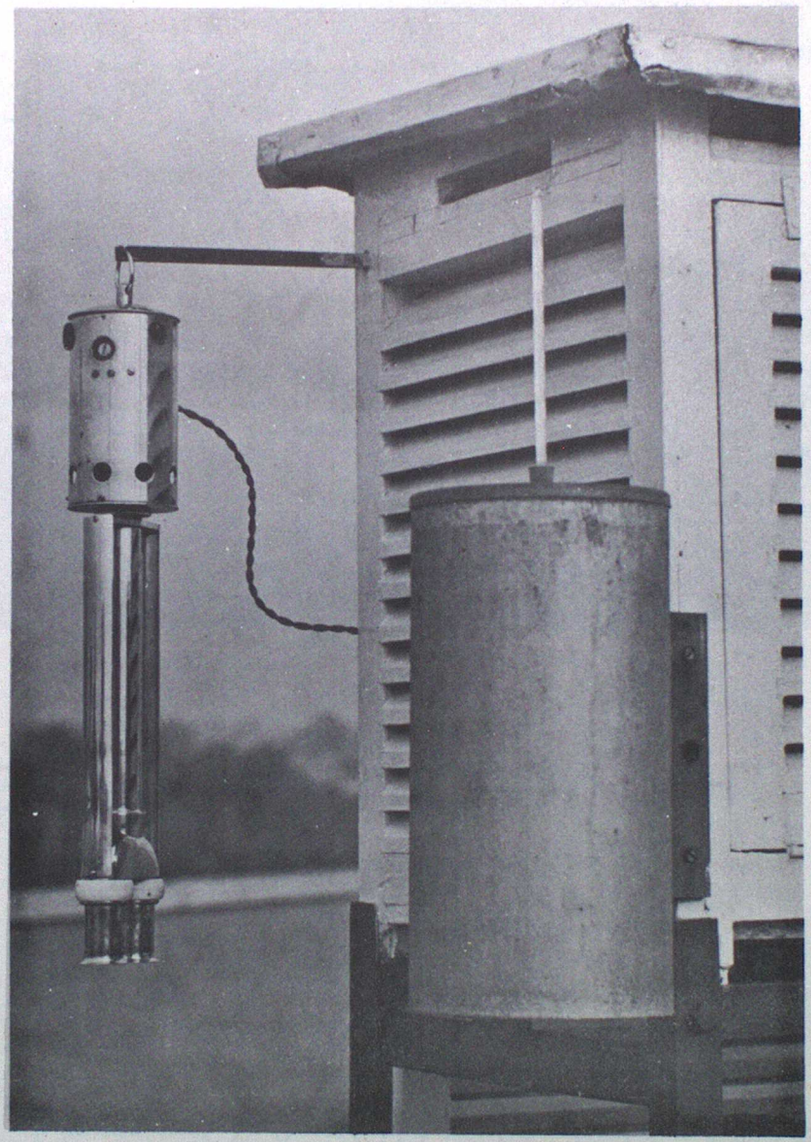

Fig. 3. Electrical hygrometer, Assmann psychrometer and screen.

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THE HYGROMETER SHIELD

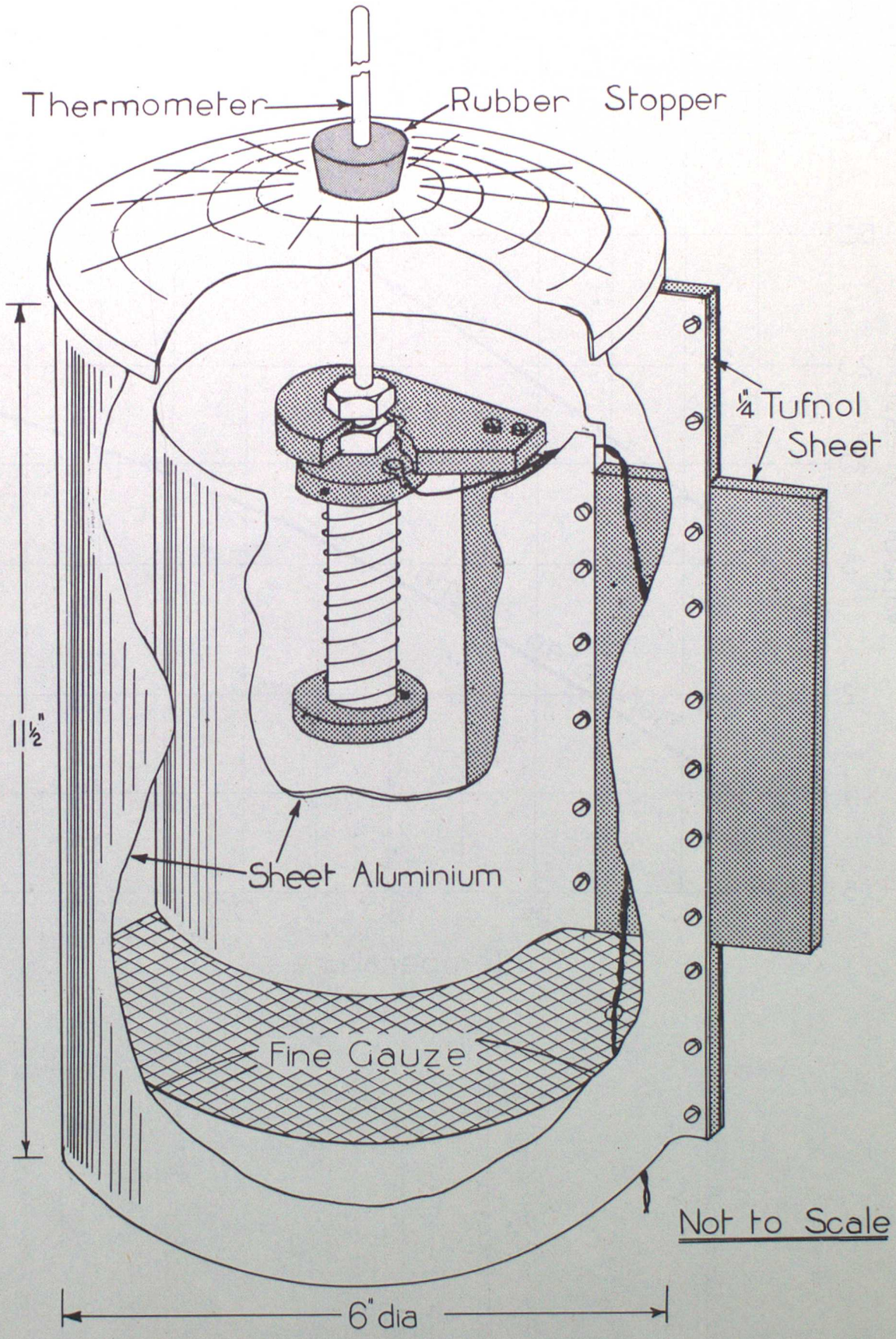


Fig 4

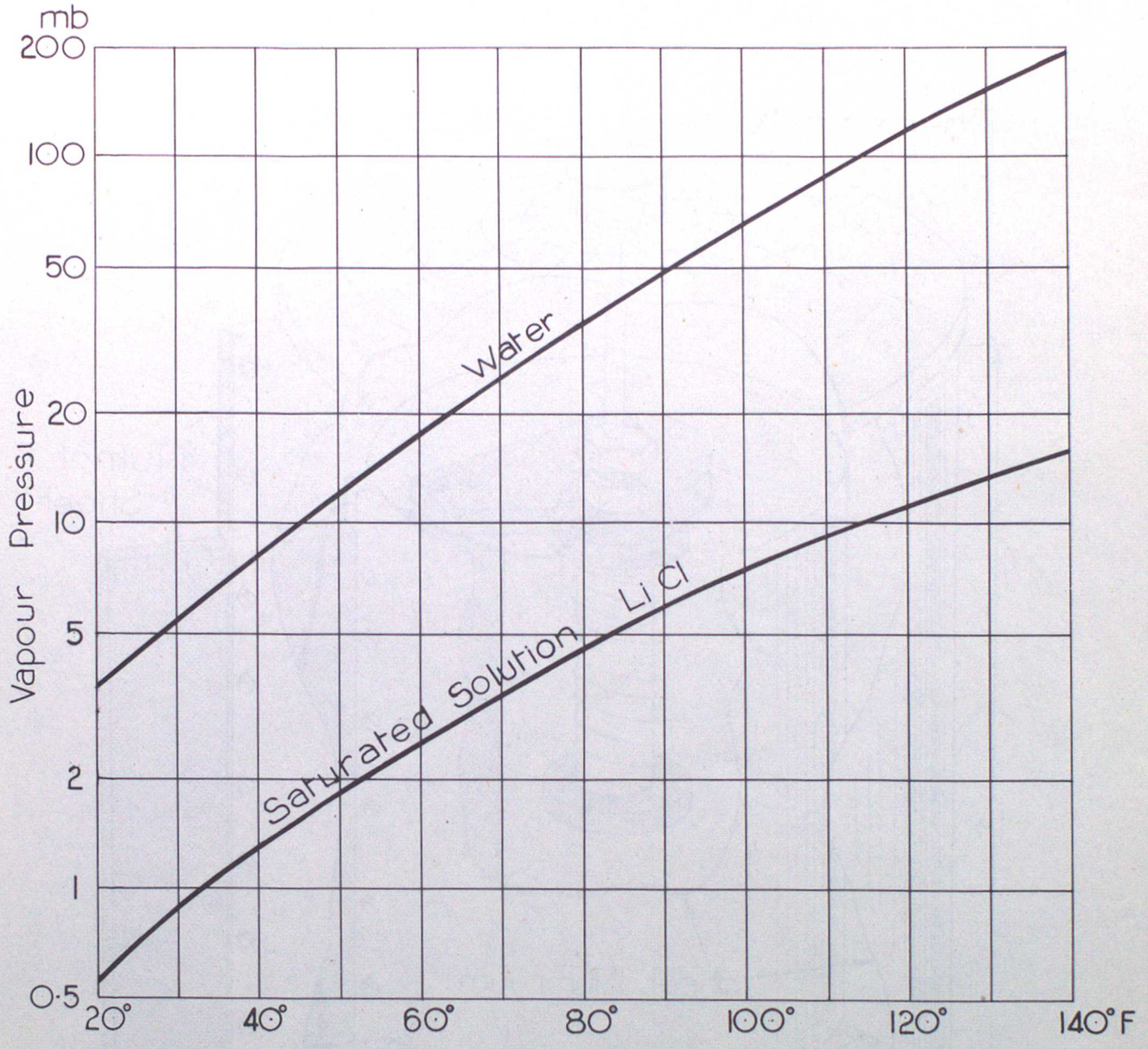

mb
200
100
50
20
10
5
2
1
0·5
Vapour Pressure
Water
Saturated Solution Li Cl
20°
40°
60°
80°
100°
120°
140° F
Temperature

Fig 5

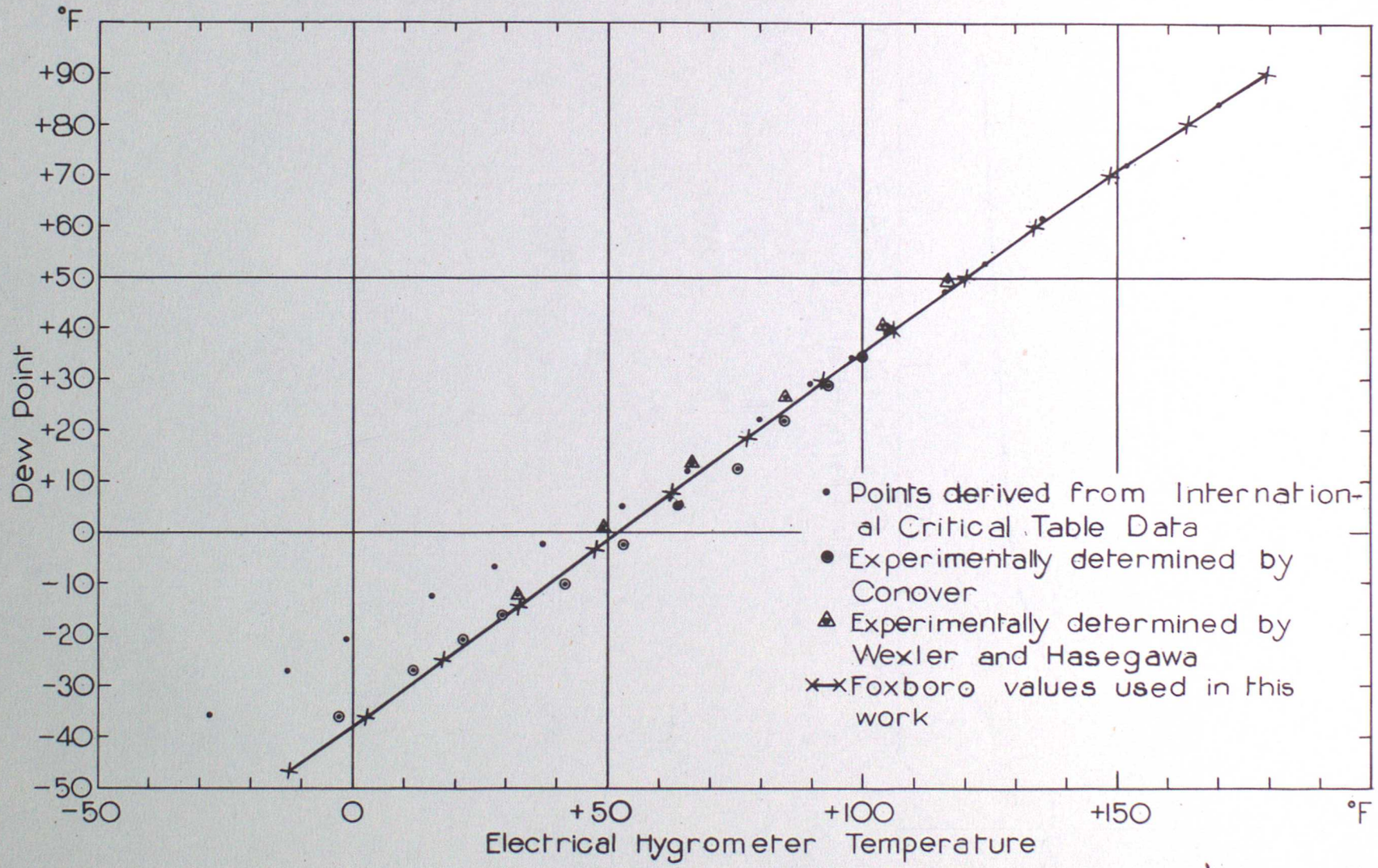


Fig 6 Relation between electrical hygrometer equilibrium temperature and dew point of surrounding air

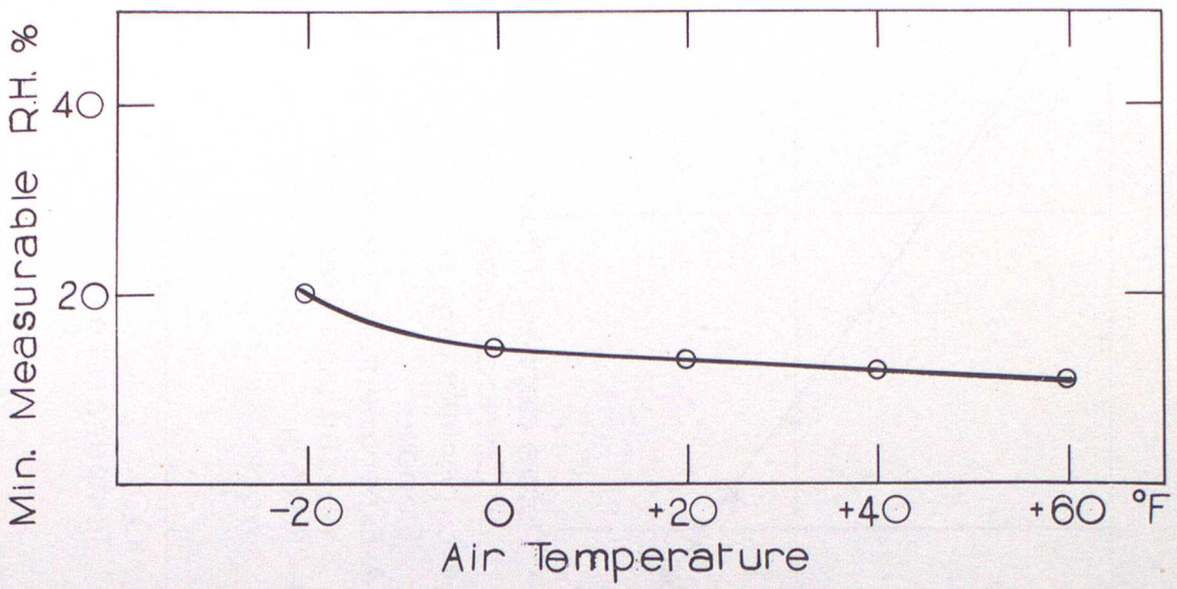


Fig 7.

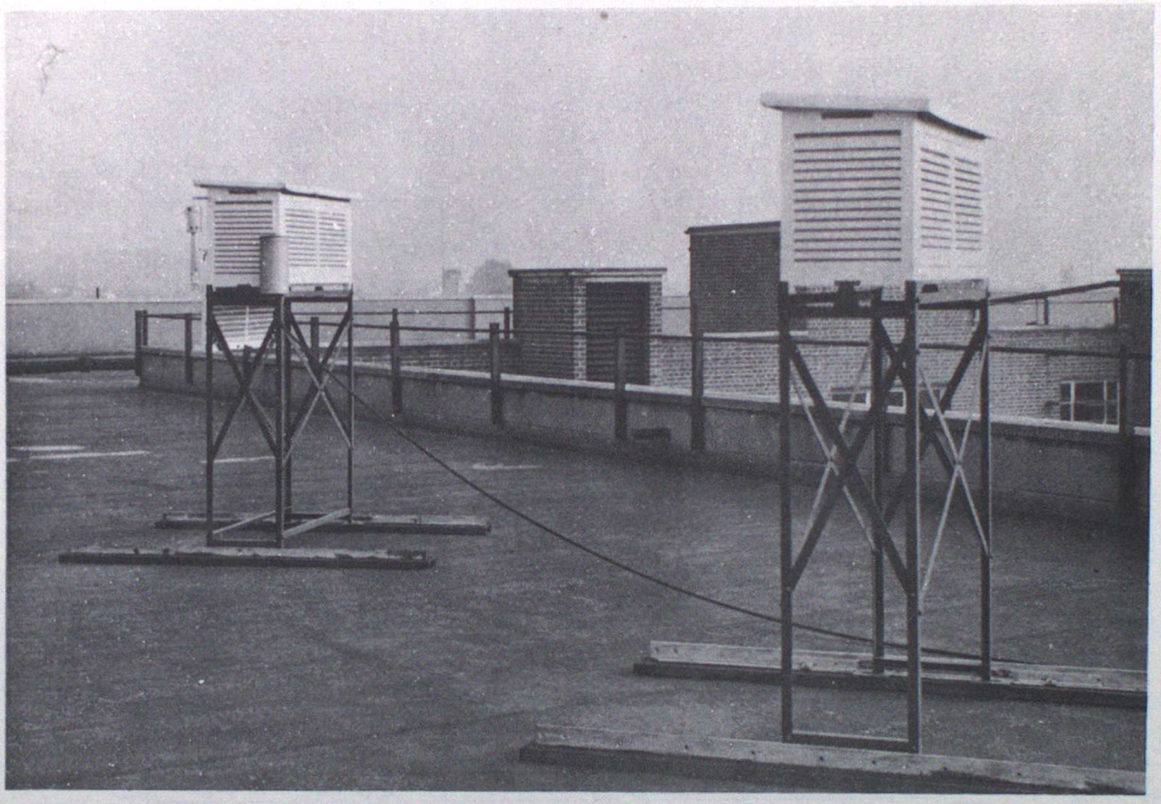
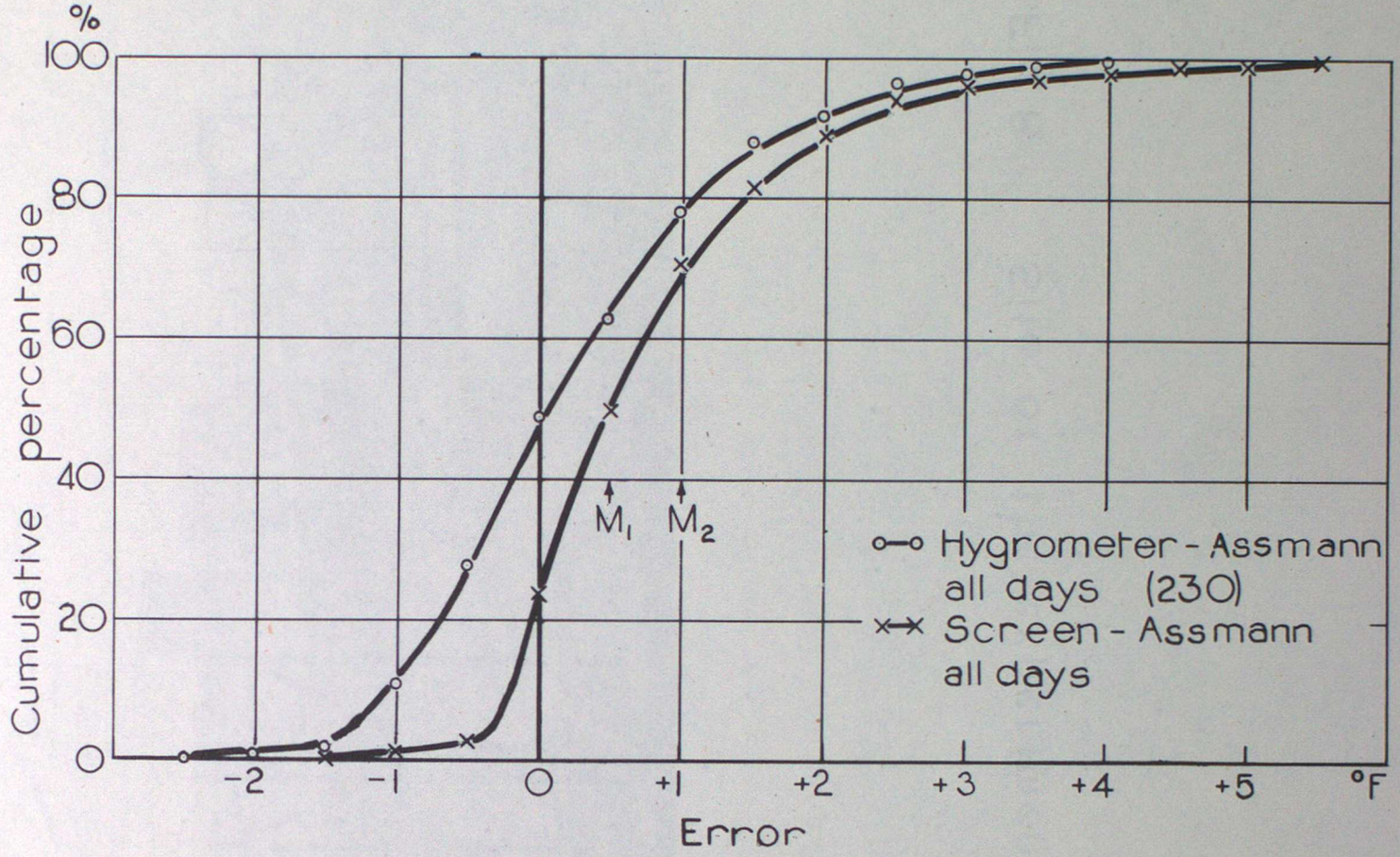
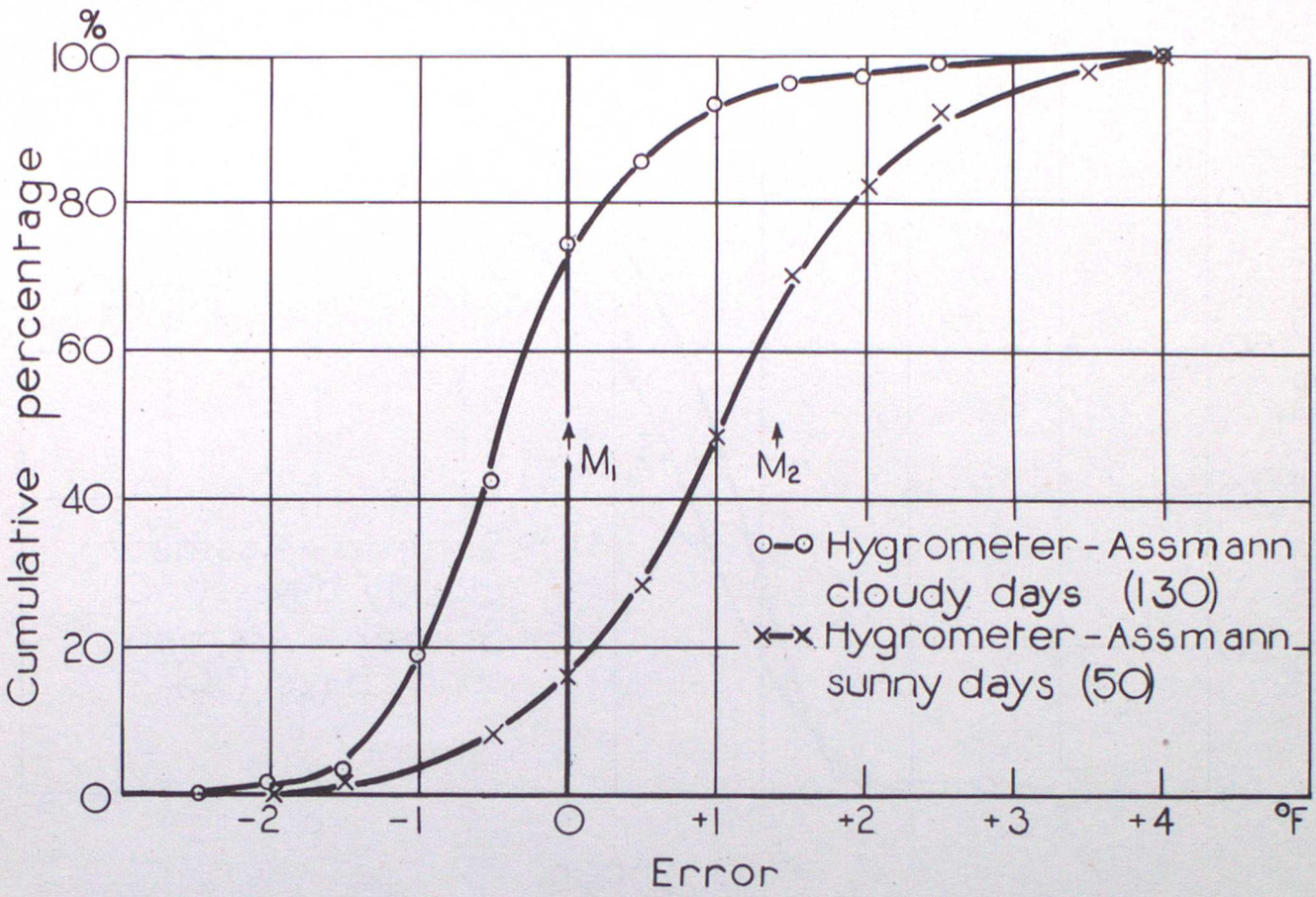


Fig. 8 Site of the experiment.



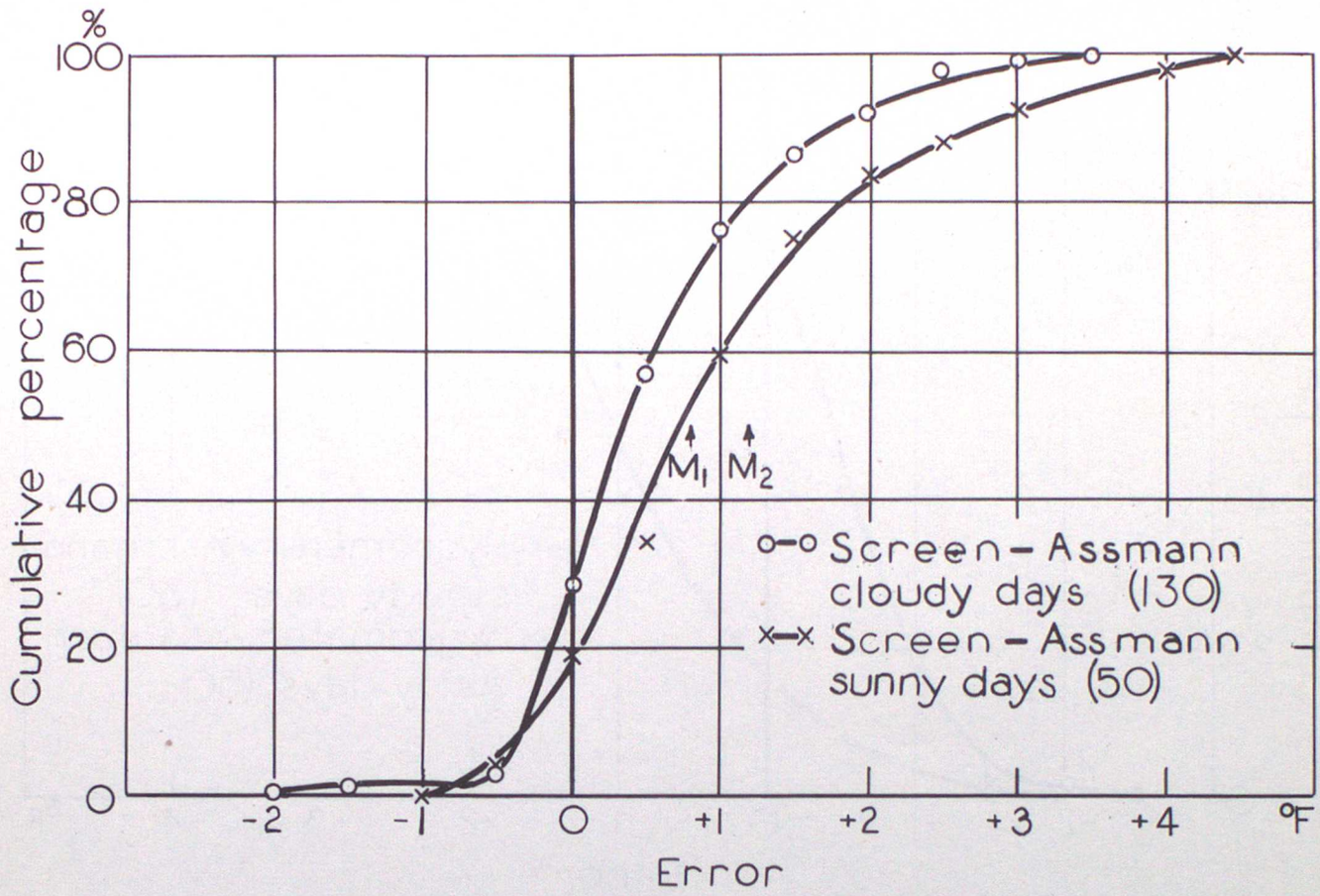
Means: Hygrometer - Assmann = M_1 = +0·5 °F
Screen - Assmann = M_2 = +1·0°F

Fig 9



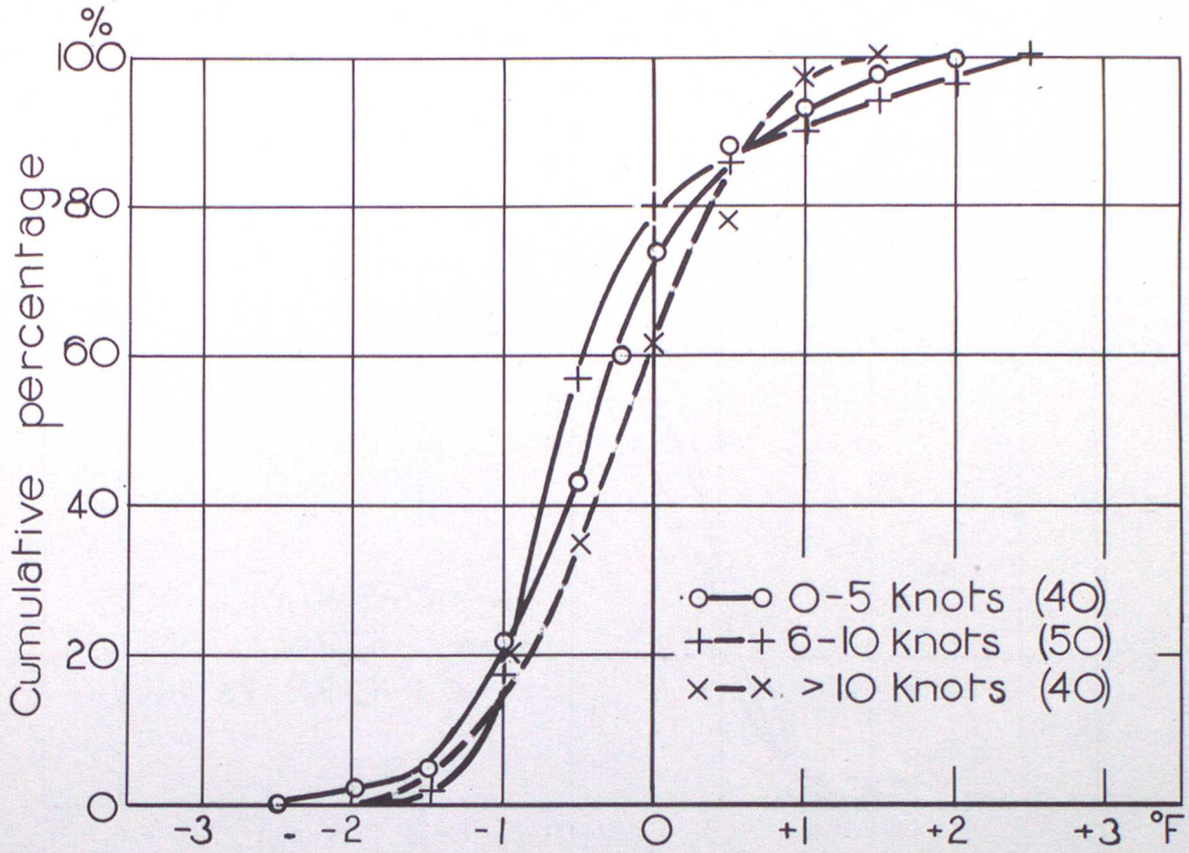
Means: Cloudy days = M_1 = + 0·0 °F
Sunny days = M_2 = + 1·4 °F

Fig 10



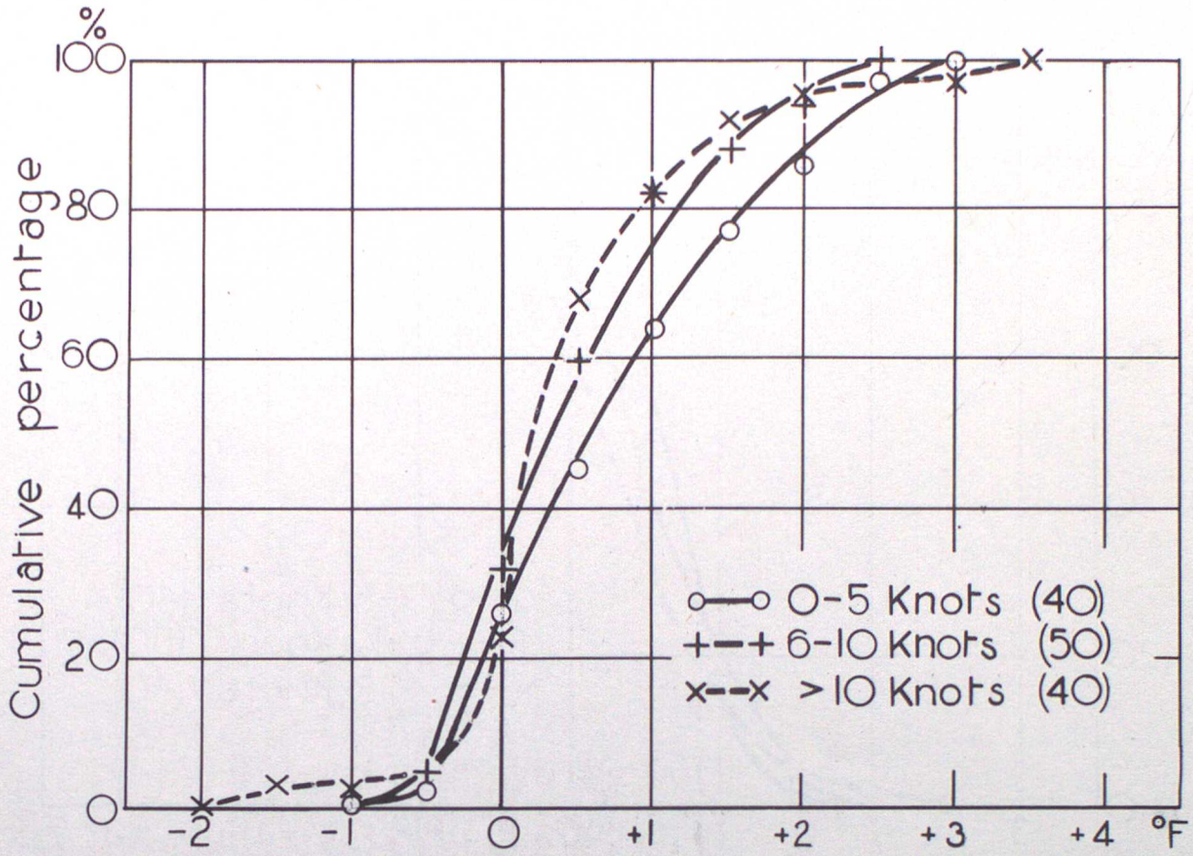
Means: Cloudy days = M_1 = + 0·8 °F
Sunny days = M_2 = +1·2 °F

Fig 11



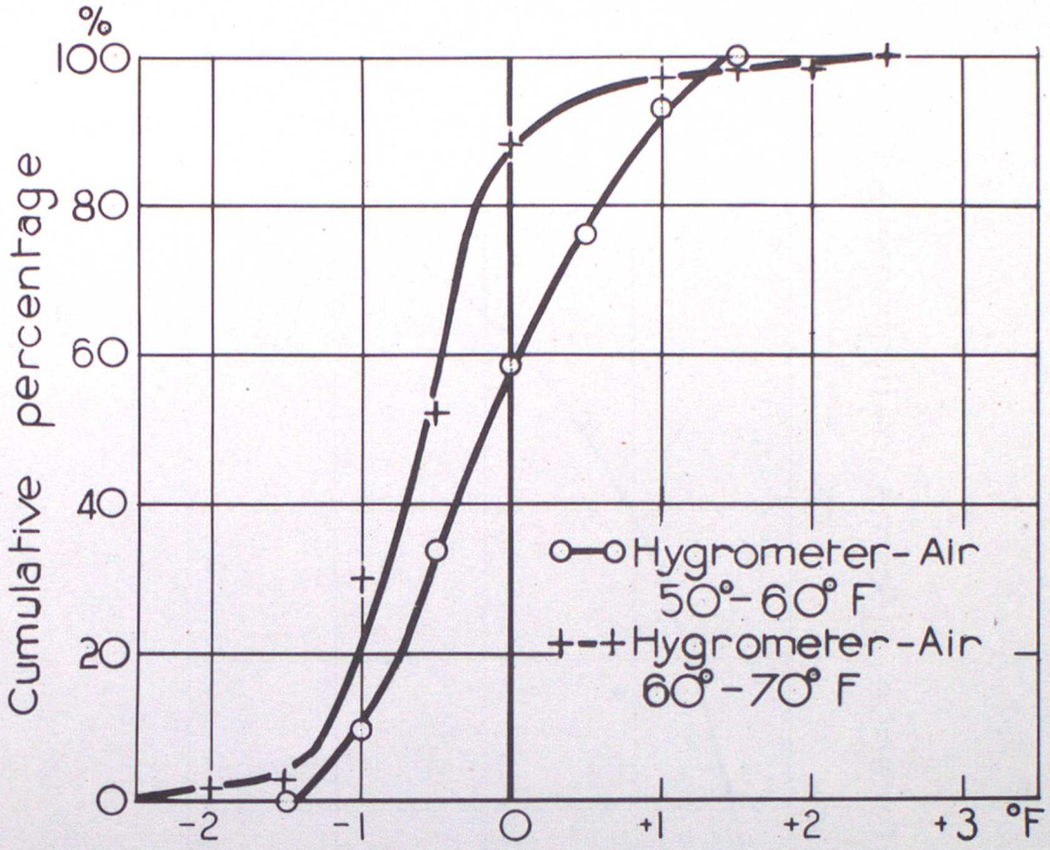
Hygrometer v Assmann
Cloudy days

Fig 12



Screen v Assmann
Cloudy days

Fig 13



Cloudy days

Fig 14

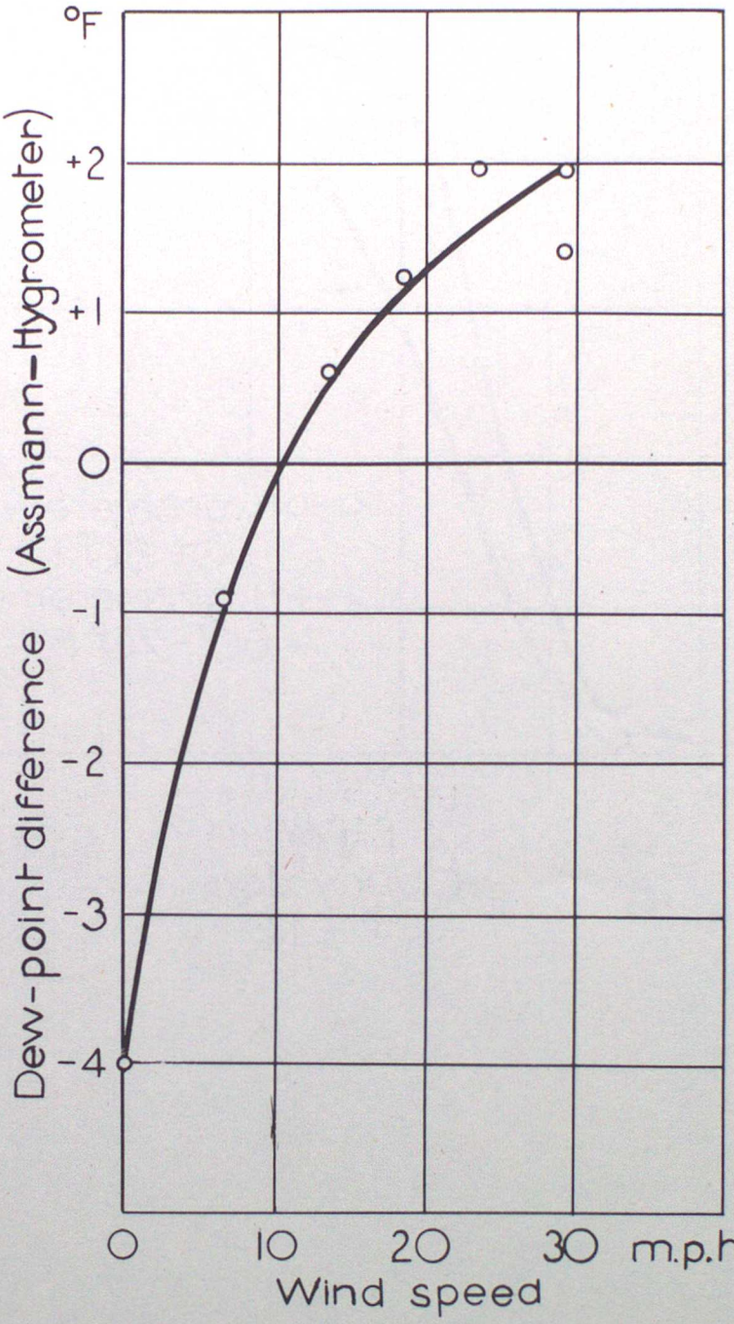


Fig 15. Effect of a steady wind on the Electrical Hygrometer.